(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 178 170 A2**

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: 85307236.1

(22) Date of filing: 09.10.85

(51) Int. Cl.⁴: H 01 L 23/48, H 01 L 21/60, B 23 K 20/22

(30) Priority: 09.10.84 JP 211960/84

(43) Date of publication of application: 16.04.86 Bulletin 86/16

(84) Designated Contracting States: DE FR GB

(71) Applicant: Kabushiki Kaisha Toshiba, 72, Horikawa-cho Saiwai-ku, Kawasaki-shi Kanagawa-ken 210 (JP)

(72) Inventor: Baba, Hiroyuki c/o Patent Division, Toshiba Corp.Principal Office 1-1 Shibaura 1-chome, Minato-ku Tokyo (JP)
Inventor: Matsuzaki, Takashi c/o Patent Division, Toshiba Corp.Principal Office 1-1 Shibaura 1-chome, Minato-ku Tokyo (JP)

(74) Representative: Freed, Arthur Woolf et al, MARKS & CLERK 57-60 Lincoln's Inn Fields, London WC2A 3LS (GB)

(54) **Semiconductor device having a bonding wire and method for manufacturing it.**

(57) A semiconductor device in which an end of an aluminium bonding wire (23) is connected to a lead electrode (25) of copper or a copper alloy in a manner such that the thickness of a reaction layer (60) is 0.2 (micron) or more. In manufacture, heat treatment is effected to bring the reaction layer (60) to the desired thickness. The semiconductor device displays excellent electrical characteristics in high temperature conditions or in high temperature high humidity conditions.

EP 0 178 170 A2

0178170
TITLE MODIFIED
see front page

M&C FOLIO: 799P50909 WANGDOC: 0404b

SEMICONDUCTOR DEVICE AND MANUFACTURING METHOD THEREOF

The present invention relates to a semiconductor device and method of manufacture thereof.

More particularly, the invention relates to a semiconductor device in which one end of a bonding wire whose other end is connected to a bonding pad of a semiconductor element is in good connection to a lead frame and which displays excellent electrical properties in high temperature conditions or in high temperature, high humidity conditions.

As shown in Fig. 1, in a conventional semiconductor device manufacturing method, a Ni plating layer 2 is formed on the surface of a lead electrode 1 made of copper, etc. and a bonding pad 5 on a semiconductor element 4 and the lead electrode 1 are connected via this Ni plating layer 2 by a bonding wire 3. The semiconductor element 4 is mounted on a solder layer 7 formed on a Ni plating layer 9 on a lead frame 8. The bonding wire 3, the bonding pad 5, the semiconductor element 4, the solder layer 7, and parts of the lead electrode 1 with its plating layer 2 and the lead frame 8 with its plating layer 9 are surrounded by a resin sealing body 6.

However, with a device in which Ni plating layers 2 and 9 are formed, there are the problems that there is considerable variation in plating quality, that the manufacturing process for effecting plating treatment is complex and that the plating treatment makes manufacturing costs higher, etc. A practice in recent years, therefore, has b en to effect direct connection of an aluminium bonding

wire 3 onto a lead electrode 1 of copper, etc. without carrying out plating treatment.

However, in testing of semiconductor devices with aluminium bonding wires 3 connected directly to lead electrodes 1 of copper, etc. in long-time shelf tests in high temperature conditions (150°C, 175°C) or in high temperature (about 80°C), high humidity (about 90%) conditions, there has been found to be a problem of reduced reliability because of opening at the bond interface between bonding wires 3 and lead electrodes 1.

A technique for resolving this problem in which bonding between bonding wire constituted by copp r wire and a lead frame made of copper is effected by selectively activating the bonding region is disclosed in Japanese Patent Application No. 55-88318. However, in this technique there are the problems that oxide forming on th bonding wire causes bond faults and that it is difficult to form a set ball at the bonding wire end portion. Further, working characteristics are poor because the bonding area has to the activated in each bonding process.

Japanese Patent Application No. 57-51237 discloses a bonding process technique in which a ball of required shap is formed and bonding oxidation is prevented by introducing a capillary end portion leading out from a bonding wire under a cover where a reducing atmosphere is maintained. However, this technique requires a complex structure including a cover for maintaining a reducing atmosphere and when the bonding process is effected at a process speed of one second or l ss there is the probl m that maintenance and control ar troublesom since faults occur easily. There is

also the problem that it is not possible to effect highly reliable bonding between bonding wire constituted by copper wire and a lead frame made of copper since it is not possible to prevent oxidation on the lead frame side where an external lead is formed.

It is an object of the present invention to provide a reliable semiconductor device which displays good electrical characteristics in high temperature conditions or in high temperature, high humidity conditions and a manufacturing method which makes possible the easy production of such a semiconductor device.

According to one aspect of this invention there is provided a semiconductor device comprising a semiconductor element mounted on a prescribed region of a lead frame of copper or a copper alloy, a lead electrode mounted or formed on said lead frame, a bonding wire which has one end connected to a bonding pad of said semiconductor element and has its other end connected to said lead electrode, and a resin sealing body which seals said semiconductor element said bonding pad and said bonding wire in a manner such that a portion of said lead frame and a portion of said lead electrode lead out to the exterior, characterised in that said bonding wire is of aluminium and the thickness of the reaction layer at the connection with said lead electrode is 0.2 (micron) or more.

According to another aspect of this invention there is provided a method of manufacturing a semiconductor device comprising a step wherein one end of bonding wire is connected to a bonding pad of a s miconductor element mounted on a lead frame of copper or a copper alloy and its other end is connected to a lead electrode of said lead frame, charact rised in that said bonding wire is of aluminium and said other end of the bonding wire is

fused to said bonding pad and in that heat treatment of the fusion connection is effected to make the thickness of the reaction layer formed by said copper or copp r alloy and aluminium 0.2 (micron) or more.

A semiconductor device according to this invention displays excellent electrical characteristics in high temperature conditions or in high tempeature, high humidity conditions thanks to the connection of an end portion of the aluminium bonding wire to the lead electrode of copper or copper alloy in a manner such that the reaction layer thickness is made 0.2 (micron) or more.

Embodiments of the invention will now be described, by way of example only, with reference to the attach d drawings, in which like reference numbers indicate lik parts and in which:

Fig. 1 is a cross-section of a semiconductor devic manufactured by a conventional method;

Figs. 2 - 5 and Fig. 7 are explanatory drawings illustrating the method of the invention in the order of steps therein;

Fig. 6 is a graph showing the relation between time and temperature for reaction layer formation: and

Figs.8 - 10 are explanatory drawings showing lead electrode and bonding wire connection states.

The method of the invention and semiconductors in embodiments thereof will now be described with reference to the attached drawings. First, as shown in Fig. 2, a semiconductor element 22 is mounted on a mount portion of a lead frame 20 made of copper or copper alloy via a solder layer 21. The copper alloy employed here may be phosphor bronze or be another copper alloy containing iron.

Next, as shown in Fig. 3, one end of 200 (microns) ø bonding wire 23 made of 99.99% pure aluminium is fused to a bonding pad 24 on the semiconductor element 22 by ultrasonic bonding process. Then, the other end of the bonding wire 23 is similarly fused by ultrasonic bonding process to a lead electrode 25 of the lead frame 20. Like the lead frame 20, the lead electrode 25 also is formed copper or a copper alloy.

Next, heat treatment is effected to make the thickness of the aluminium and copper or copper alloy reaction layer formed at the portion where the bonding wire 23 and l ad electrode 25 are fused together 0.2 (micron) or more.

As shown in Fig. 4, in order to effect heat treatment on the lead electrode 25, heaters 40 and 42 with a temperature

of about 600°C hold the lead electrode 25 from above and below and transfer heat at a location where the lead frame 20 has been advanced to posiition I. Successive shifts of the lead frame 20 from the left towards the right as seen in Fig. 4 are effected about once every 1.2 - 1.3 second. That is, one-time contact of the heater 40 gives insufficient transfer of heat for formation of a reaction layer of 0.2 (micron) or more and so formation of a reaction layer with a thickness of 0.2 (micron) or more is brought about by the provision of heaters in a number of places combined with shifts of the lead frame 20. Fig. 4 illustrates the case where there are two places, I and II. In this embodiment, the heater contact time is about 0.5 seconds and heaters are provided in five places. Fig. 5 shows a cross-section of the state of Fig. 4 seen from the side. In Fig. 5, the lead frame 20 is set on a pedestal 50, which is provided with a blow hole 52 for a mixed gas containing nitrogen for cooling the lead frame 20. This is in order to prevent melting of the solder layer 21 due to the lead frame 20 being heated by the heaters 40 and 42 as well as the lead electrode 25. An air atmosphere may be used for the heat treatment but since the copper or copper alloy frame is oxidized as h ating proceeds it is preferable to have a non-oxidizing atmosphere or a reducing atmosphere. In this embodiment, use is made of a mixed gas containing 90% N_2 and 10% H_2. The non-oxidizing gas employed here may be inert gas, be reducing gas or be mixed gas thereof. For exampl , the inert gas may be argon or helium and the reducing gas may b hydrogen. Fig. 6 shows the relation between time and temperature for

reaction layer formation In this embodiment, the temperature of the bonding portion 26 is set at 400 – 450°C and heating treatment is effected to give a total amount of intermittent heating time of about 5 seconds. Heating is not limited to being intermittent heating, it being simply necessary to have a total heating time of about 5 seconds.

Although description was given above with reference to a heating method in which elements are held between heaters, another method that may be employed is to effect heating for several tens of seconds to several minutes during passage of the lead frame through a hydrogen oven or a nitrogen oven at a temperature of 350 – 400°C. Other methods include a method in which the lead electrode 25, leaving out the bonding portion 26, is heated with a burner torch, a method in which the lead electrode 25 is heated using a resistance welder and a method in which the lead electrode 25 is heated using a laser. Further, there is no restriction to these methods but any other method apart from these may be used as long as it permits heating with the temperature and time controlled in the range of the upper portion including the shaded portion of Fig. 6.

From the constitutional diagram and sectional examination of the abovenoted reaction layer, the composition of the reaction layer is inferred to be Al_2Cu, AlCu.

Subsequently, as shown in Fig. 7, mold treatment is effected to give a semiconductor device 30 in which the semiconductor element 22, lead frame 20, bonding wire 23 and lead electrode 25, etc. are sealed as an integral unit in resin sealing body 27.

Since connection of the bonding wire 23 and lead

electrode 25 is effected with formation of a reaction layer that is 0.2 (micron) or more in the semiconductor device 30 thus produced, it is made possible to prevent opening faults in the bonding wire 23 and lead electrode 25 bond portion even in high temperature conditions or high temperature, high humidity conditions, and as a result there is produced a highly reliable semiconductor device 30. Also, the manufacturing process is simplified and manufacturing cost can be reduced since there is no need to effect plating treatment on the lead frame 20 and lead electrode 25.

The reason for making the thickness of the reaction lay r formed by the aluminium and copper or copper alloy 0.2 (micron) or more is that, as is made clear from the test examples described below, products that are rejects because of opening faults occur in high temperature conditions or high temperature, high humidity conditions if the thickness is less than 0.2 (micron).

As illustrated in Figs. 2 - 5 and Fig. 7, semiconductor elements 22 were mounted in a non-oxidizing atmosphere on lead frames 20 of copper or copper alloy on which plating layers had not been formed and then aluminium bonding wires 23 bridging bonding pads 24 of the semiconductor elements 22 and lead electrodes 25 of lead frames 20 were attached by ultrasonic bonding process. Next, mold treatment of these assemblies was effected to give semiconductor devices (Test Products 1). In this case, as illustrated in Fig. 8, no plating layer was formed on the surface of the lead electrodes 25 and there was no reaction layer present

between the bonding wires 23 and the lead electrodes 25.

Semiconductor devices constituting Test Products 2 were manufactured by mounting semiconductor elements 22 and bonding bonding wires 23 and lead electrodes in the same way as for Test Products 1 after thorough reduction of the lead frames 20 in a high temperature reducing atmosphere.

Semiconductor devices were produced in the same way as Test Products 2 except that reaction layers 60 were formed between the bonding wires 23 and lead electrodes 25 as shown in Fig. 9 by heat treatment following connection of the bonding wires 23 and lead electrodes 25. In this case, devices with a reaction layer 60 thickness of 0.1 (micron) or less were taken as Test Products 3, devices with 0.2 – 0.5 (micron) as Test Products 4, devices with 0.5 – 1 (micron) as Test Products 5 and devices with 1 – 2 (microns) as Test Products 6.

Semiconductor devices produced in the same way as Test Products 2 after preliminary formation of Ni plating layers 70 on the lead frames 20 and lead electrodes 25 as shown in Fig. 10 were taken as Test Products 3.

High temperature shelf tests consisting of 500 hours, 1000 hours, 1500 hours, 2000 hours and 2500 hours or more at 150°C and 300 hours, 500 hours, 1000 hours and 1500 hours or more at 175°C were conducted on 20 each of the semiconductor device Test Products 1 – 7 produced in the abovedescribed manner. Investigation of occurrence of rejects because of opening faults between bonding wires 23 and lead electrodes 25 gave the results noted in the following table.

TABLE

Temperature at which left	150 °C					175 °C				
Sample / Hours left	500	1000	1500	2000	2500	300	500	1000	>1500	
Test Product 7	0	0	0	0	0	0	0	0	0	With Ni plating layers
" 1	0	0	2	10	20	1	7	20	–	With no Ni plati layers and reaction layers
" 2	0	0	0	3	7	0	0	5	13	"
" 3	0	0	0	1	3	0	0	3	6	Reaction layer <0.1 micron
" 4	0	0	0	0	0	0	0	0	0	0.2 – 0.5 micron
" 5	0	0	0	0	0	0	0	0	0	0.5 – 1 micron
" 6	0	0	0	0	0	0	0	0	0	1 – 2 microns

As is clear from the above table, the number of rejects occuring because of opening faults becomes smaller as the reaction layers formed by the copper or copper alloy and aluminium is larger and it is seen that when the thickness of the reaction layer is 0.2 (micron) or more high reliability equivalent to that of devices with Ni plating layers in displayed.

Long-term shelf tests at high temperature and high humidity (80°C, 90%) were conducted on the abovedescribed semiconductor device Test Products 1 - 7 and it was found that there was similarly no occurrence of rejects when the reaction layer thickness was 0.2 (micron) or more. Futher, similar results were obtained in thermal impact tests (-45°C $\longleftrightarrow$ 150°C) and thermal fatique tests too.

As described above, with semiconductor devices and method for their manufacture according to the invention, it is possible to easily produce highly reliable semiconductor devices which display excellent electrical characteristics in high temperature conditions or in high temperature, high humidity conditions.

CLAIMS

1. A semiconductor device (30) comprising a semiconductor element (22) mounted on a prescribed region of a lead frame (20) of copper or a copper alloy, a lead electrode (25) mounted or formed on said lead frame (20), a bonding wire (23) which has one end connected to a bonding pad (24) of said semiconductor element (22) and has its other end connected to said lead electrode (25), and a resin sealing body (27) which seals said semiconductor element (22), said bonding pad (24) and said bonding wire (23) in a manner such that a portion of said lead frame (20) and a portion of said lead electrode (25) lead out to the exterior, characterised in that said bonding wire (23) is of aluminium and the thickness of the reaction layer (60) at the connection with said lead electrode (25) is 0.2 (micron) or more.

2. A method of manufacturing a semiconductor device (30) comprising a step wherein one end of bonding wire (23) is connected to a bonding pad (24) of a semiconductor element (22) mounted on a lead frame (20) of copper or a copper alloy and its other end is connected to a lead electrode (25) of said lead frame (20), characterised in that said bonding wire (23) is of aluminium and said other end of the bonding wire (23) is fused to said bonding pad (24) and in that heat treatment of the fusion connection is effected to make the thickness of the reaction layer (60) formed by said copper or copper alloy and aluminium 0.2 (micron) or more.

3. A method according to claim 2, characterised in that said heat treatment consists of heating effected with said lead electrode (25) held between heater elements (40, 42).

4. A method according to claim 3, characterised in that holding by said heaters (40, 42) is effected intermittently or continuously for a set time.

5. A method according to claim 3 or claim 4, characterised in that non-oxidizing gas is blown onto said lead frame (20) from below during heating by said heater elements (40, 42).

6. A method according to claim 2, characterised in that said heat treatment consists of heating by passage through a hydrogen oven.

7. A method according to claim 2, characterised in that heat treatment is effected by heating said lead electrode (25) apart from said bonding portion (26) with a burner torch.

8. A method according to claim 2, characterised in that said heat treatment consists of heating said lead electrode (25) by a resistance heating system.

9. A method according to claim 2, characterised in that said heat treatment consists of heating said bonding portion (26) by laser irradiation.

10. A method according to claim 5, characterised in that said non-oxidizing gas is inert and/or reducing gas.

11. A method according to claim 11, characterised in that said inert gas is nitrogen, argon or helium and said reducing gas is a hydrogen.

PRIOR ART

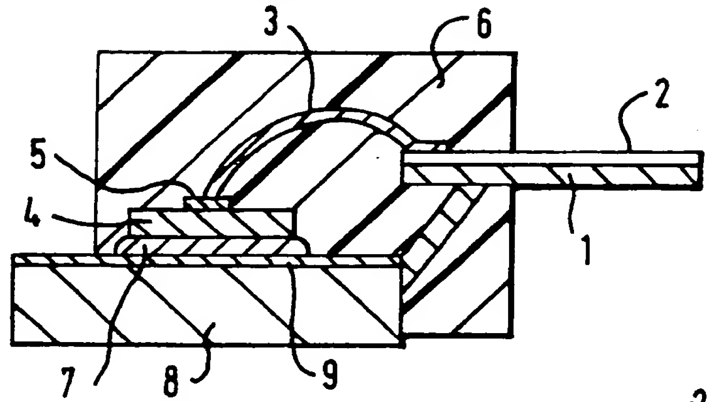

FIG.1.

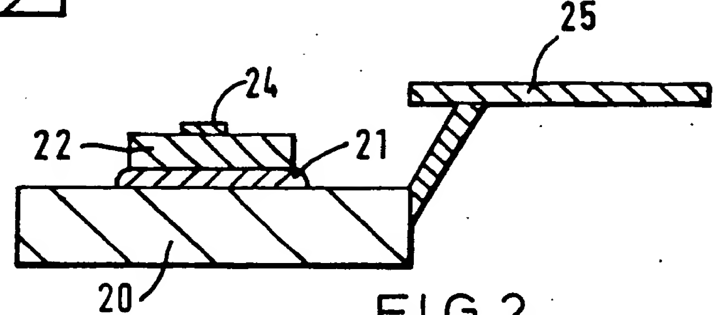

FIG.2.

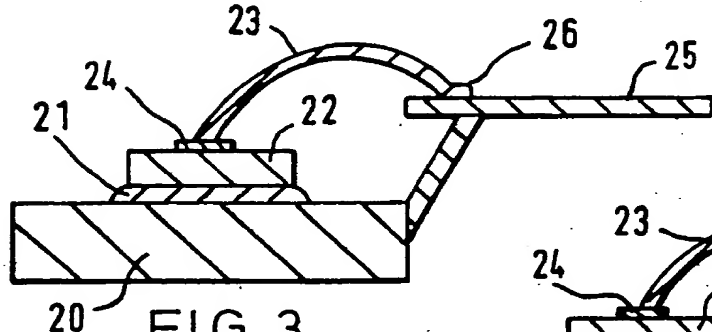

FIG.3.

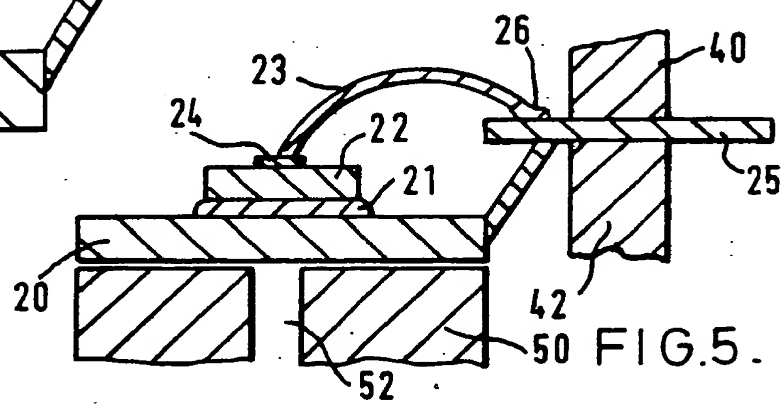

FIG.5.

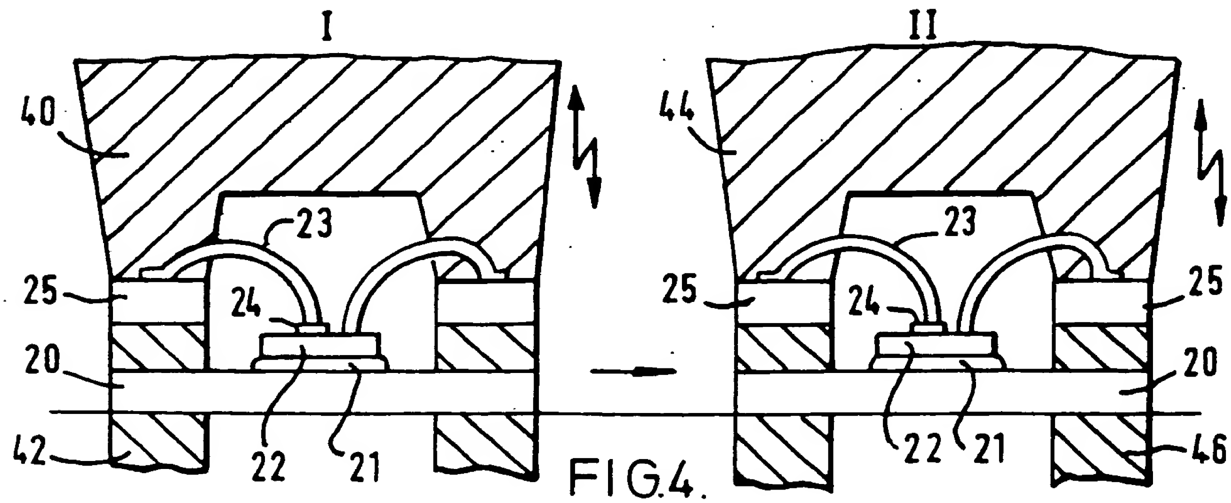

FIG.4.

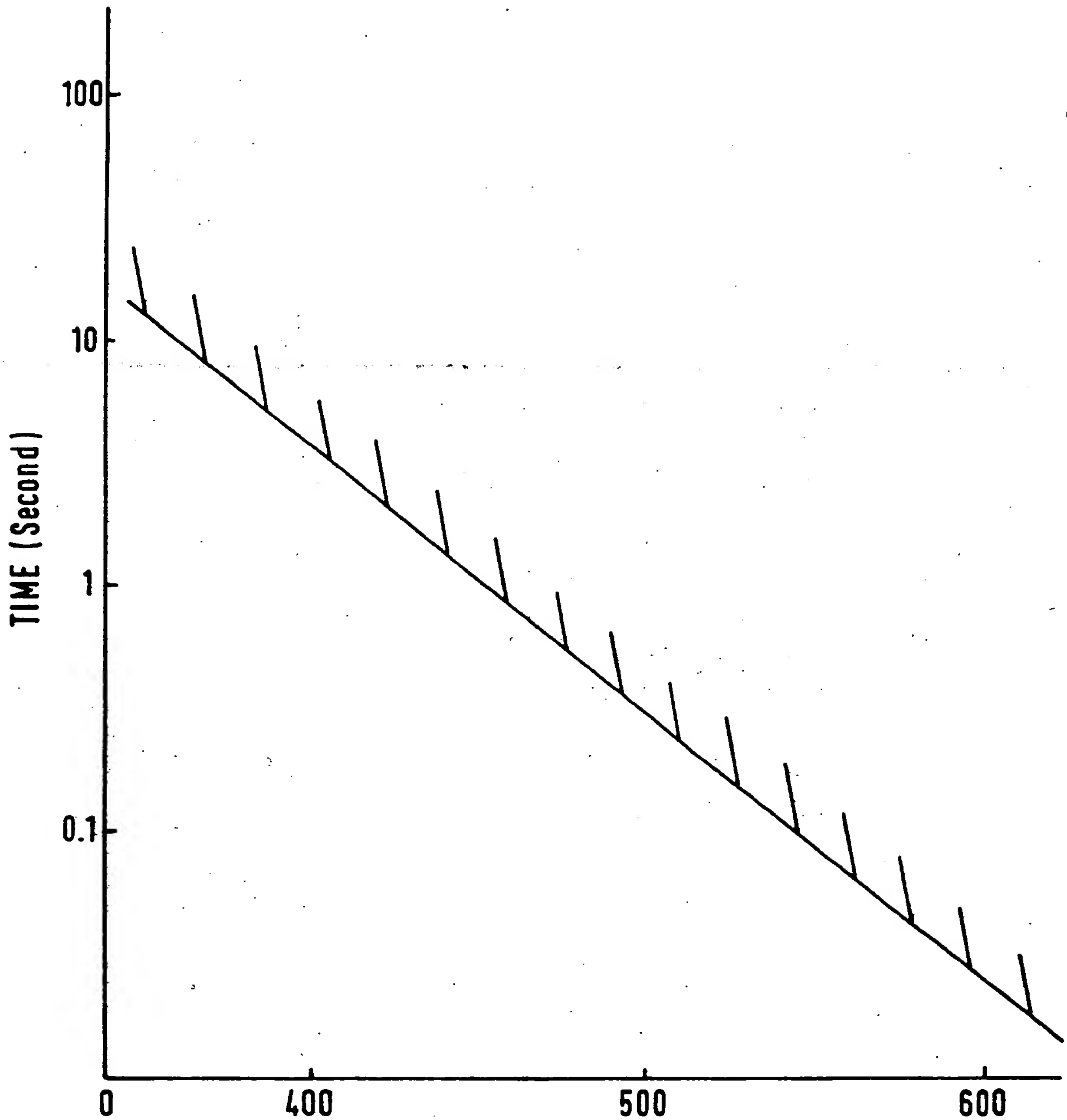

FIG.6.

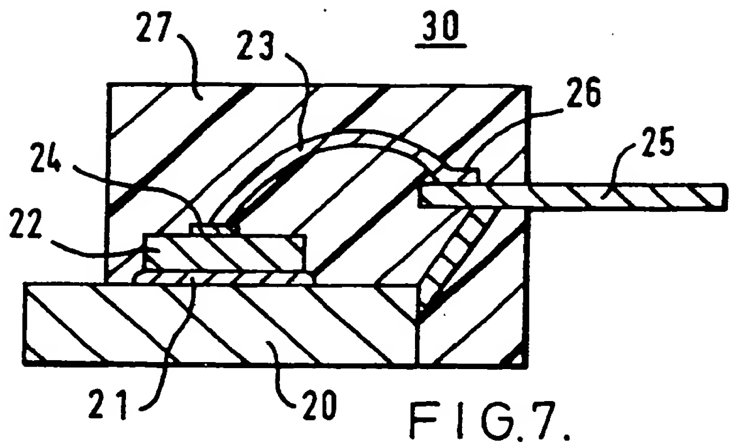

FIG.7.

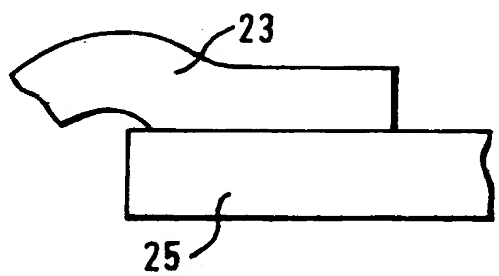

FIG.8.

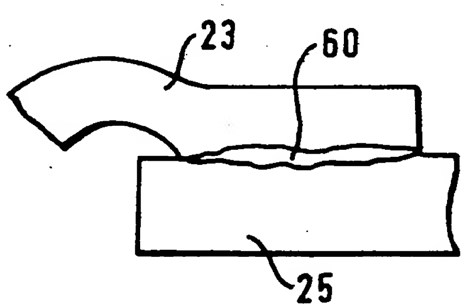

FIG.9.

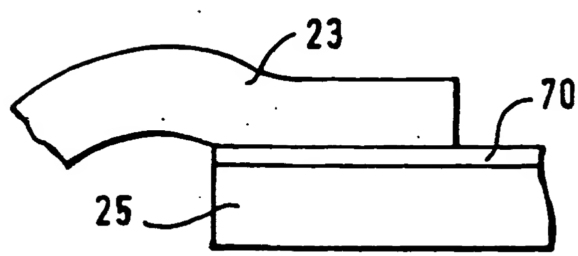

FIG.10.